

Flame Synthesis of Carbon Nanotubes Using Low Calorific Value Gases

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OBJECTIVE(s)

The proposed exploratory research has two primary objectives to achieve the flame synthesis of carbon nanotubes using low calorific value gases. The *first objective* is to identify the most favorable flame conditions of low calorific value gasses (LCVG) to produce carbon nanotubes. The second objective is to explore the possibility of systematically controlling those conditions to increase the yield of the synthesis process. The flame conditions, which will be considered in the first objective, will be evaluated in terms of (i) overall fuel (reactants) flow rates and compositions, (ii) catalyst characteristics and spatial locations, (iii) local flame temperature, and (iv) local flow velocities.

ACCOMPLISHMENTS TO DATE

The reactor (a laminar diffusion flame burner system) for flame synthesis of carbon nanotubes has been assembled and qualified. The reactor consists of a stainless steel tube burner with a length/diameter ratio of 20 and an exit diameter of 1.8 mm, which is connected inside a closed optically accessible combustion chamber. To modify the flame flow-fields another circular burner with slotted exit has also been fabricated. The modified burner is capable of generating a known amount of turbulence in the vicinity of the nanotube formation zone. The aluminum walled combustion chamber has three windows to provide optical access for non-intrusive flow diagnostic methods. Experiments are supported by air and fuel intake systems, air exhaust systems, and safety systems and data acquisition instrumentation. The air intake and air exhaust systems are designed to maintain a constant pressure level inside the combustion chamber. During a typical run the flame inside the chamber burnt only 5-8% of the chamber air. Two remotely operated spark igniters initiated the combustion process.

Flame synthesis of carbon nanostructures including nanotubes on galvanized steel was investigated utilizing laminar diffusion flames of different types of fuel. Pure methane (CH_4), propane (C_3H_8) and acetylene (C_2H_2) were used to quantify the nanotube formation

characteristics of base fuels. Distinctive carbon nanostructures were produced depending on fuel types and fuel flow rates. The qualitative and quantitative analysis of transmission electron microscope (TEM) and scanning electron microscope (SEM) images were performed. Methane produced thin multi wall carbon nanotubes as well as nanorods and nanofibers within the fuel flow rate range of $7.18 \times 10^{-7} \text{ m}^3/\text{s}$ to $9.57 \times 10^{-7} \text{ m}^3/\text{s}$. Propane yielded nanotubes only at the fuel flow rate of $4.20 \times 10^{-7} \text{ m}^3/\text{s}$. The nanotubes synthesized by acetylene flames were of different types that included helically coiled and twisted nanotubes.

FUTURE WORK

Flames of various fuel mixtures representative of different compositions of coal derived LCV fuels will be studied to observe the conditions at which they produce the highest yield of carbon nanotubes. The catalyst substrate (iron, nickel and cobalt) will be inserted at different height above the burner exit for a certain amount of time. The nanoparticles formed on the catalyst substrate will be collected and deposited onto silicon monoxide/formvar-coated, 3mm TEM (200 mesh copper) grids for observation in a Hitachi H-8000 analytical TEM operating at 200 kV accelerating potential. In addition selected-area electron diffraction (SAED) patterns will be also recorded for particular matter of interest. These experiments will allow understanding the effects of fuel compositions on the yield and structures of carbon nanotubes. In addition, spectroscopic and LDV measurements will be done upstream and downstream sides of the collection points to evaluate the local flame temperature and flow velocities. This study will allow generating phenomenological and parametric relationships between the fuel compositions, flame kinetics and local flow-field with the yield of carbon nanotubes.

Once the relationships are identified, a combination of fuel compositions (by adding selective reactive and inert gases) and flow-field modification (by introducing a higher level of turbulence near the carbon nanotube formation zone) will be used to enhance the flame conditions to increase the yield of nanotubes.

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